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OVERVIEW OF THE WORK WITHIN CEN TC 250/ SC5/ WG12 ASSESMENT AND RETROFITTING OF TIMBER EXISTING STRUCTURE

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ABSTRACT: The CEN/TC250 initiative to form WG2 "Assessment and retrofitting of the existing structures" and after that the Horizontal group under the same title, was motivated by the visible growth and extensive construction activities regarding the assessment and retrofitting of existing buildings and also by engineering works that are aligned with the new agendas for decarbonisation and generally for a sustainable construction sector. The agenda promotes the importance of extending the service life of existing assets, thereby achieving economic, environmental, and socio-political benefits. The scope of the CEN TC 250 SC5/ WG12 is to provide general requirements and procedures for the assessment and retrofitting of timber existing structures (buildings, bridges, industrial structures, etc.). The complexity of the current environmental and climate situation reflects on the design practice today demanding an integrated and coordinated planning process. Consideration of all the factors of sustainability leads to complex, integrated design procedures for structures that do not have to satisfy only mechanical properties like before. Therefore the Construction Products Regulation identifies in its Annex I the following basic requirements for the construction: 1. mechanical resistance and stability; 2. safety in case of fire; 3. hygiene, health and environment; 4. safety and accessibility in use; 5. noise protection; 6. energy efficiency and heat retention; 7. sustainable use of natural resources.

KEYWORDS: existing structures, assessment, retrofitting, interventions, timber

1 – INTRODUCTION

General principles of sustainable development regularly lead to the need for extension of the life of the structure, in the majority of cases in practice, in conjunction with severe economic constraints. The approach for the assessment and retrofitting of existing structures is in many aspects different from that of designing new structures. The direct application of design-orientated methods for new structures to the assessment and retrofitting of the existing, often leads to a high degree of conservatism and heavy interventions that increase the cost and in parallel change the identity of the building, especially the heritage ones. This is why the assessment of existing structures often requires the application of sophisticated methods either on-site, or at the stage of structural analysis, as a rule beyond the scope of design codes for new structures. New technical Standards, regulations and not just guidelines for the assessment and retrofitting of the timber existing structures should provide the basis and give tools to practise, in order to master this new challenge. Therefore CEN/TC250 had taken the initiative to prepare a document to evaluate the purpose and justification for new European technical rules and related standards for evaluation and retrofitting of existing structures for different materials (concrete, masonry, steel and timber). The discussions in CEN/TC250 confirmed the need to form a CEN working group (WG2), for the further development of the subject.

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It resulted in the technical specifications CEN/TS 17440:2020; "Assessment and retrofitting of existing structures: general rules and actions", and the document CEN TC 250 WG2 T2: "Requirements and guidance on the development of material-specific", which was the basis for the discussion inside Eurocode 5 Committee (CEN/TC250/SC5), that decided in forming AHG for Timber existing structures. Since the topic is very wide and important, and needs a lot of efforts, the new working group WG12 "Assessment and retrofitting of the existing structure", was established. This paper presents the principles and the main axes on which its future work program will be based, concerning the existing timber structures.

2 – PRESENT AND FUTURE DESIGN PHILOSOPHY

During the past 25 years according to the fundamental requirements, a structure should be designed, executed and maintained in such a way that it will, during its intended life, with appropriate degrees of reliability:

- sustain all actions likely to occur during execution and use,
- remain reliable and safe for the use for which it is required.

These fundamental requirements stipulate the concept of the limit state design, which is differentiating:

- ultimate limit state referring to the structural safety,
- serviceability limit states.

It has to be emphasised that these fundamental requirements are mainly restricted to the mechanical properties and behaviour of the structure and its parts. Most today's structural design codes are based on semi-probabilistic methods describing the design values with appropriate partial factors.

The fundamental requirements with regard to safety and serviceability and the principles of limit states for the design of new structures apply currently also for the existing structures, historical or not. However the technical rules for the design of new structures often are not appropriate for the assessment and finally the retrofitting/restoration or reinforcement of the existing ones. Whereas the design is taking into account uncertainties in the anticipated use of a structure, the assessment considers the history of a structure and the future use equally. The concepts of the future urban planning will be based on new economic, technological and social ideals focussed on the care for the environment as well as on increasing the quality of life. To reach these main objectives, designers must improve the quality of buildings (resilience to climate change, thermal comfort, indoor environment, etc.) as well as the concepts and quality of the engineering works thus making the foundation for the new principles of building concepts. The future of construction works will be very much governed by the sustainable development of infrastructures, urban and industrial areas, which results in extensions, reuse or rehabilitation of existing buildings or structures generally. The requirements in terms of structural safety are defined through the acceptable probability of failure or targeted value of reliability index or the acceptable level of risk. The deformation/deflection limits for historic structures can be different and less strict from the ones that the modern codes specify (serviceability limit state design) for a new timber structure.

2.1 SUSTAINABLE DEVELOPMENT

Since adoption of the Kyoto protocol in 1997, the sustainable development has been a long term goal of the global policy not only in the EU but worldwide. The building and construction sector plays an important role in sustainable development. The environmental impact of the construction sector is very considerable: total energy consumption: ~40%; consumption of raw materials: ~50%; waste streams: 40 – 50%. In this context the assessment and retrofitting of existing structures is one of the leading goals for sustainable development in the construction sector. The rate is increasing steadily during the last 30 years and the plans are that it will continue to increase in the future.

Real estate agents, owners of existing buildings, stakeholders and other partners interested in the technical performance of the structure, are interested to profit from a successful assessment or retrofitting in achieving a higher value on the real estate or rent market. The convergence between the rediscovery of traditional methods and the development of robust engineering approaches to the design of timber structures has created a unique environment for the development and dissemination of reliable and comprehensive approaches to the assessment of existing and historic timber structures. Regarding the bridges the situation is somewhat different from that for buildings. Especially the reasons for assessing bridges and the impulse for maintenance intervention are different; however, the principles are the same and the methodologies are comparable. Traffic has increased significantly leading to

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an increasing number of heavy vehicles in the traffic. Because of environmental considerations there is also a tendency to further enhance the admissible loads in the design of new heavy vehicles. Bridge authorities are therefore interested in agreed methods to assess the safety, and durability of existing bridges and to make appropriate provisions for more refined methods for the evaluation and maintenance. This includes the design of new timber buildings taking into account future needs of disassembly and maximising reuse possibilities, but also the reuse of reclaimed materials in new buildings.

3-MAIN TOPIC FOR ASSESSMENT

3.1. INTRODUCTION

Despite relatively large numbers of technical papers, few international standards related to in situ evaluation of timber exist. The purpose of the safety assessment is to determine whether the structure is at present adequate to carry the loads that it is required to carry and will continue to be adequate for the foreseeable future. The specific rules for timber buildings, in the new code for existing buildings, have to contain specific criteria as a first step for the assessment of timber structures in their present state and as second for their retrofitting, when necessary. The assessment of a timber structure is mainly needed because of a change of the use of the building, the presence of damages, apparent or suspected alterations/interventions in the structure, poor initial design or/and construction, and poor maintenance. Two main categories belong in existing structures:

a) heritage structures (historical, traditional, protected or not), being built without the use of Standards and

b) existing buildings of the 20th and 21th century, designed and constructed with the use of the relevant Standards of each period and each country that they belonged. The assessment procedure and methodology has to take into account the differences and the similarities that these categories present.

Heritage structures differ from other existing structures in that a greater value is placed on their fabric because of their historical significance, and for this, more precise and expensive methods for their assessment and their restoration/reinforcement may be needed. Moreover, they present a huge variety of structural systems and construction details (joints of different type, different workmanship, non-standardized fasteners as timber pegs, or iron nails of rectangular section etc.), that depend on local building traditions that may go back in time hundreds of years.

The EN 17121 "Historic Timber Structures - Guidelines for the on-site Assessment of Load-Bearing Timber Structures", being published in 2019 within the aims of CEN/TC 346-Conservation of cultural property, is the only approved EN that exists till now, concerning existing buildings in the frame of Eurocodes and relevant ENs. It was based on relevant work and paper produced in Cost Action IE0601-WoodCultHer. Though it is not applicable to timber members made of engineered wood-based panels, glued laminated timber and other industrial made types of timber, it can be a firm base concerning the assessment procedure, methodology and the criteria that have to be developed for the existing timber structures. Several works and publications have been also made in the framework of the Cost Action FP1101 in WG1, for the assessment of timber structures.

3.2. THE ASSESSMENT PROCEDURE

The assessment procedure has to be both qualitative and quantitative, on-site and on desk. A holistic approach is necessary, considering and evaluating the structure as a whole, and not just individual members and joints, taking also into account the interaction of load-bearing elements and non-load bearing ones, or the interaction and connection with substructures that support the timber structure (e.g., in a masonry building with timber roof). Because of this, a horizontal collaboration has to be established with the other parts of the Standard for Existing Buildings (CEN/TC250, WG2), that concerns the relevant materials (masonry, reinforced concrete, steel, etc.).

The first part of the assessment procedure is the collection, documentation and recording of the information about the original and existing condition of the structure, through:

- Desk study of historical information, phases, load history, workmanship, protection treatments, drawings, old photos, Technical Reports and specifications for the design and construction, written or oral records for previous problems, changes of use, interventions or maintenance works etc. For pre-1940 timber structures, original design documents are rarely available.

- On-site visual inspection and measured geometric survey: layout and precise geometry of the overall load bearing system and the timber members, joints of timber members, joints of timber members with the supporting structural elements or other type of elements as steel braces. Concerning joints, the precise distances of the fasteners from the edges and the ends of

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the connected elements are crucial for the assessment of their load bearing capacity.

- Recognition of the used material (timber species of solid timber, glued laminated timber, derived wood products and composites with other construction materials, metal fasteners, type of adhesive etc.).

- Recognition of the structural system, identification of the lateral load bearing system, of diaphragms and of their connection.

A preliminary structural analysis has to be conducted in order to determine the overall forces and general levels of stress within the structure, and in more detail to verify the critical sections and areas (highly stressed or deformed areas[2], where more attention is required concerning survey and pathology), guide and set the assessment strategy for the pathology and the assessment of materials (grading of specific timbers, evaluation of fasteners etc.). It is important that the results of the structural analysis are compatible with the recorded pathology of the structure. It must be noted, that the structural analysis is important also for the grading of the existing timbers since it depends highly on their structural type (members in tension, compression, bending or combination). This way the grading of existing timbers may be less conservative and strict compared with the grading of new timbers. The location and stress conditions of historic timbers are known as are the positions of specific growth characteristics, thus allowing the importance of defects to be evaluated in relation to the applied stresses. Because of the diversity of existing visual strength grading rules in use in different countries, the relevant part may be determined at national level (National Annexes).

The collection of data and measurements pertaining to both historical and current environmental conditions is essential. Furthermore, the classification of structural components and joints into Service and Risk categories, based on various hazards such as biological threats and fire, may need to be specifically developed for existing structures. It has to be noted that different parts or members of a timber structure can belong to different use classes.

On-site recording of the existing condition of the structure and pathology, by visual inspection, and the use of semi or non-destructive methods (SDTs and NDTs), in order to identify damages on members and joints, evaluate mechanical properties (strength grading), residual/effective cross-sections, dangerous zones of the structure, condition of any adhesive bond, and also the possible need for immediate propping/safety measures/access restriction. Samples may be taken if necessary. The lateral force resisting system, diaphragms and their connection to the lateral force resisting system. must be evaluated, too.

Geometry, damage mapping and deformation (deflections, displacements, warping etc.) of members, or of the whole structure can be measured too, by new 3d laser scanning and photogrammetric methods.

The second part of assessment concerns the diagnosis of the timber structure which includes the interpretation of the general structural behavior of the structure original and present, of the damages and of the existing condition of the structure at different scales, as a whole and as individual members, joints, materials.

A second more detailed structural analysis of the existing condition may follow, taking into account all the above, the loading conditions, the pathology and the material and joint properties (see relevant chapters), the overall stability, since the structural modeling is an important part of the diagnosis procedure. It is important that the results of the structural analysis are compatible with the recorded pathology of the structure, and the estimated behavior of the load bearing system, in order for the structural model to be used as the basis for the necessary interventions and also for the model that will evaluate them (restoration/reinforcement stage). Special attention must be given also to the structural model of the whole building of which timber structures are a part (roofs, floors, timber framed walls), their role and interaction with the other structural parts, especially in seismic areas.

The final overall assessment of the timber structure (existing condition, state of strength and stiffness), is the last step of the assessment procedure. Possible factors and classifications may be used as in FprEN 1998-3-2025 (E) - 10 for existing timber buildings in earthquake zones (Condition assessment factors, Knowledge level and factor, Condition assessment criteria, Classification of diaphragms, timber frames, and joints).

4 – DESIGN UNCERTAINTIES

Design uncertainties arise from the prediction of load and resistance parameters of a new structure. These uncertainties represent the variability of a large population of structures caused by the unequal qualities of material and the different construction practices.

The main topics to be considered are therefore:

- Methodology of collecting, evaluating and updating data.

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- Recommendations for application of partial factor method and direct use of probabilistic methods consistent with those for new structures.

- Target reliability level of existing timber structures taking into account residual working life time, consequences and costs of safety measures.

- Assessment based on satisfactory past performance.

- Resistance models for the assessment of timber structural elements constructed with detailing provisions and tolerance than those assumed in design standards.

There is a clear difference in the design of new and existing structures, not least regarding the information and its quality available for the prediction of the structures behaviour. For an existing structure is necessary to gather data in order to be able to assess the ability of such a structure to carry the required loads and continue to be in use both now and for the foreseeable future, and to identify those areas of the structure that require repair or strengthening.

On the contrary, at the time when a new structure is designed, the only information available are the codified values of loads specified for the intended location, shape and purpose of the building as well as the resulting projected geometrical and material properties (e.g. strength class of timber member). On the basis of such general information either a deterministic design using the partial safety factor concept or a so-called prior probabilistic design can be formulated. For example, it is unknown how many defects in the specific timber element will exist in the location of the highest loading or how the wind speed and snow height will accumulate during the lifetime of the building. As soon as the building is built and finalized much more information about the actual realisation of the structure is available. For example, the properties of the actual structural timber members can be assessed and quantified, e.g. the grain structure, growth ring width, and defect distribution resulting in its strength and stiffness. Hence, the knowledge and information about the structure can be updated by more precise information of the actual realisation. At the same time the environmental loads and especially the expected impacts from local climate or imposed loads can be considered for the verification of the reliability and safety of the existing structure.

Important factors that determine the loads on the structure are generally the specific geographical location, exposure of the structure in relation to its environment, and the metrological and environmental conditions at the site. Hence, not only the material properties but also other aspects for the structure can be updated, such as geometry of the structure, local climate, materials used in the structures, damages and deterioration, support conditions, loading history and survival of certain load conditions, static and dynamic response to controlled loading.

While the information about the load and its updating is treated according to respective part of the Eurocode, the environmental impact of the local climate as well as the impact of the loading history on the timber structure need to be considered in the timber specific part. Timber has hydrophilic properties and is dependent on the load duration, speed, moisture content, and load variation. Hence, the load history can have a considerable impact on the properties of the timber in the future of the building's service life. As a result the respective modification factors require a careful review for an implementation in a design code of assessment of timber structures.

Although verification of serviceability limit states may also be important in certain cases, higher limits (namely for deflection and vibrations) than those defined in new codes may be acceptable for heritage structures.

EN 1998-3 (Eurocode 8: Design of structures for earthquake resistance–Part 3: Assessment and retrofitting of buildings and bridges), that incorporated a new chapter for timber existing structures can be followed concerning the design of existing timber structures in earthquake zones.

5 – CURRENT APPROACH

SIA 269/5:2011 assumes that there is no difference between old and new solid timber with respect to its properties of strength and stiffness, provided the timber is not mechanically or biologically damaged. This also applies to glued laminated timber, derived wood products and glued solid timber, if there is no detachment of the adhesive composite (delamination).

The unfavourable influence of mechanical and biological deterioration to the timber, for example as result of overloading, shrinkage (cracks), detachment of the adhesive composite (delamination) as well as attack by insects and fungi, shall be taken into consideration when determining the structural and deformation behaviour.

5.1. QUANTIFICATION OF MATERIAL PROPERTIES

In the annexes/parts of the Eurocode 5 relevant to existing structures, the clauses will provide the information to be obtained by the tests, such as the number of specimen and the sampling procedure. Destructive, non-destructive tests or a combination of both can be considered. Loading and environmental conditions will be specified in the clauses. The clauses are planned to recommend which standards should be applied and highlighting their limits of applicability. For cases in which standards are not applicable (e.g. absence of a standard for the case under study, test conditions that are different from those recommended in the standards), the clauses may suggest specific test procedures. Typical uncertainties related to the testing procedure should be provided and will be needed for the derivation of respective material partial factors, as illustrated in the example of Annex C in prEN1990-2.

Resistance models and thus the partial factors associated with their uncertainties will be calibrated to achieve the level of reliability required for the relevant assessment situations. The annexes/parts relevant to existing structures should contain clauses specifying the assumptions and relevant information associated with the partial factors that cover the uncertainties of the resistance models. Here we can distinguish a) resistance models for design, b) resistance models for assessment; c) resistance models for rehabilitation.

5.2. STRUCTURAL ANALYSIS

The structural analysis of an historic structure is a difficult process with many uncertainties because it is not always possible to estimate the residual/effective cross section, the strength and stiffness of structural members and joints, the load history, or the boundary conditions and in general the load bearing capacity of the structure.

Typically, structural analysis presumes a linear correlation between stress and strain. However, for structural components and connections under compressive stresses, particularly those made of steel that can undergo plastic deformations, a non-linear (elastic-plastic) behavior might be considered in the analysis if the areas in question have adequate deformation capacity.

During structural analysis, the results from the condition survey (such as stresses, deformations, and deterioration) should be depicted in a manner that accurately captures the structural and deformation behavior (see Assessment). Specifically, SIA 269/5:2011 advises considering the following: i) the potential type and direction of force transmission in joints; ii) joint yielding; iii) eccentricities in force transmission and joints; and iv) the impact of construction methods (including construction and loading history) and structural changes.

Once the structure's geometry is established, an initial analysis can be conducted to pinpoint critical systems and components, aiding in the planning of inspections of construction details and material property tests. This preliminary analysis, using nominal properties, is generally linear elastic for timber structures.

The timber cross-section dimensions, ascertained during the condition survey and in relation to the equilibrium moisture content for the remaining service life, are used as the updated cross-sectional dimensions. The values revised based on the condition survey are applied as the strength and stiffness values.

The effects of action duration and moisture levels on deformations must be evaluated. Creep deformations should be assessed by considering the duration and magnitude of past permanent and quasi-permanent actions. According to SIA 269/5:2011, the expected creep deformation of solid timber and glued laminated timber over their remaining lifespan can be estimated with this guideline: approximately one-third of the total creep deformation occurs after about one week, another third after roughly one year, and the complete creep deformation is reached after around 30 years.

Conducting tests that assess variations in deformation or strain can be advantageous for understanding structural and deformation behavior, as well as for calibrating models used in structural analysis.

When evaluating the load-bearing capacity of joints with metal dowel-type fasteners, it is crucial to consider the yield strength, embedment strength, and axial resistance of the fastener. Carpentry joints must be assessed for their capability to transfer compression forces through direct contact and friction, which may involve examining the pressure contact areas between connected parts. It is essential to verify carpentry joints for shear cracks, tension failures, and crushing. However, checking for rolling shear failure across the grain and tension failure along the grain can be omitted if the eccentricity, e, between the intersection of the center lines of the connecting members and the support does not exceed the depth, h, of the notched member.

5.3 STRUCTURAL INTERVENTIONS

Based on the conclusions of the assessment of the structure and/or the nature and extent of damage, decisions should be taken for the intervention. The selection of the type, technique, extent and urgency of the intervention should be based on the structural information collected during the assessment of the structure.

The structural intervention must be capable of identifying all significant local deficiencies, such as those causing early brittleness or instability, which need to be properly

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addressed. Any intervention should enhance local ductility and deformation capacity, while ensuring that the increase in strength does not significantly diminish the overall ductility available.

Various intervention strategies can be considered, including local or comprehensive alterations to both damaged and intact components, such as repairs, enhancements, or complete replacements, focusing on their stiffness, strength, and ductility. This may involve adding new structural elements, altering the structural system by removing certain joints or vulnerable parts, or reorganizing it into more regular and ductile configurations. Additionally, a new structural system might be introduced to support some or all of the design loads, or existing ancillary elements could be converted into structural components. Other options include restricting or changing the structure's use or partially demolishing it.

6 – MAIN TOPICS FOR THE RETROFITTING

New technologies in retrofitting offer very efficient methods for improving the quality of existing structures in a general view and for upgrading their behaviour with regard to sustainability in particular. The design of remedial intervention is based on a strategic decision of the owner of an existing structure. Maintenance interventions have to consider technical, operational, and economic criteria.

Basic principles for retrofitting are:

- Compatibility of structural components and materials of the old structure and the new structure in view of structural behaviour and durability, which leads to optimisation with synergic action.

- As far as historic structures under protection of monuments are concerned: reversibility of the structural intervention so that future generations can modify the technology without any damage to the features of the historic construction.

- Specific assessment and retrofitting methods are linked with regional peculiarities reflecting shortcomings in old national design or execution standards or the use of particular materials or building techniques.

7 – INTERFACE TO THE EN EUROCODES FOR STRUCTURAL DESIGN

The proposed new European technical rules for existing structures TS 17440:2020: Assessment and retrofitting of existing structures: general rules and actions, are related to the principles and fundamental requirements of the EN Eurocodes.

Thus, the technical rules for timber existing structures are not self-standing rules but they complement rules of the relevant EN Eurocodes by identifying and distinguishing the differences between the design of new structures and the assessment and retrofitting of timber existing structures. It is recommended that the part for the basis of assessment, complementary to the current EN 1990 for design, should address to the following items:

- General (scope, references, assumptions, terms and definitions).

- Requirements.

- Updating information (general, actions, material properties, geometrical properties, structural models, resistances and deformations).

- Structural analysis and verifications (verification by partial factors, verification by probabilistic methods, risk analysis).

- Examination (procedures, condition survey, condition evaluation, concept of interventions).

- Interventions (retrofitting and modification, survey and monitoring, maintenance, immediate safe ty interventions).

It is recommended that the part interfacing EN 1991 for actions on structures should give methods for updating actions and describe specific load models for existing structures taking into account the future use of the structures.

The standards for the existing timber structures should, where possible and reliable, provide provisions regarding characteristic values of building materials from the past as well as connections and structural details frequently used. The EN 1995 new parts covering existing structures should focus on the specific rules for updating information of material properties as well as on refined models for them. In addition they may describe refined models for the analysis of the structural behavior at ultimate and serviceability limit states and for the calculation of the structural resistance.

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The main issue of timber material oriented rules concerns the methodologies for concepts of interventions including retrofitting and strengthening of the timber existing structures.

The specific aspects of assessment and retrofitting of existing structures exposed to seismic actions is the scope of Part 3 of EN 1998.

8 – CONCLUSIONS

As presented, CEN TC 250/ SC5/ WG12 ASSESMENT AND RETROFITTING OF TIMBER EXISTING STRUCTURE awaits extensive work in the coming period. Changes at the level of CEN TC 250 continue to increase the importance of the issue of introducing clauses related to existing structures in all materially related Eurocodes, that's why CEN TC 250 Horizontal group HG Existing structures is formed. Convenor of the CEN TC 250/ SC5/ WG12 Assesment and retrofitting of the timber existing structure will be a member of this new Horizontal Group. It will be possible to exchange experiences with members, i.e. liaison persons from EC2 - EC9, at regular meetings of the Horizontal Group.

9 – REFERENCES

[1] Eurocode 5: Design of Timber Structures -- Part 1-1: General -- Common Rules and Rules for Buildings (EN 1995-1-1:2004/A2:2014) pp. 19– 30.

[2] EN1990: Eurocode – Basis of structural design. Brussels: CEN, 2002.

[3] Vrouwenvelder ACWM, Scholten NPM: Assessment criteria for existing structures. Structural Engineering International, 1/2010, 62-65.

[4] ISO 13822: Bases for design of structures - Assessment of existing structures. Genève ISO,2010.

[5] ISO 2394/DIS: General principles on reliability for structures. Geneve: ISO, 2013.

[6] JCSS Probabilistic Model Code. JCSS Internet publications, 2001.

[3] JCSS Probabilistic Assessment of Existing Structures. RILEM publications, 2005.

[4] Macchioni N., Bertolini C., Tannert T., Review of Codes and Standards, Kasal B, Tannert T (2010) In Situ Assessment of Structural Timber. Springer, Heidelberg. http://dx.doi.org/10.1007/978-94-007-0560-9RILEM 2010

[5] Cruz H, Yeomans D, Tsakanika E, Macchioni N, Jorissen A, Touza M, Mannucci M, Lourenço PB (2015) Guidelines for on-site assessment of historic timber structures. International Journal of Architectural Heritage 9(3):277–289

https://doi.org/10.52202/080513-0004